DOCUMENT RESUME

ED 412 502 CS 012 935

AUTHOR Yeung, Alexander Seeshing
TITLE Reading English as a Second Language with Vocabulary Definitions: Cognitive Load Effects on Comprehension and Vocabulary Learning.
PUB DATE 1997-10-18
NOTE 14p.; Paper presented at the "Our Schools Our Research" Conference (Macarthur, New South Wales, Australia, October 18, 1997).
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *English (Second Language); Foreign Countries; Grade 5; Grade 8; *Instructional Effectiveness; Intermediate Grades; Junior High Schools; *Reading Comprehension; Reading Research; *Vocabulary Development
IDENTIFIERS *Cognitive Load; Hong Kong

ABSTRACT

Two experiments were conducted to examine the effects of cognitive load management using vocabulary definitions in reading passages for readers of English as a second language (ESL) with different levels of expertise who were attending school in Hong Kong. Experiment 1 found that vocabulary definitions integrated within a passage (integrated format) improved fifth graders' comprehension, whereas a separate vocabulary list (separated format) improved vocabulary learning. Experiment 2 found that the integrated format improved eighth graders' vocabulary learning, whereas the separated format improved comprehension. The efficiency of instruction depends partly on its ability to manage cognitive load associated with the learning task. An identical presentation format may facilitate learning by reducing cognitive load but may interfere with learning either through split-attention or redundancy effects, depending on the expertise of the learner. (Contains 28 references and 2 tables of data.) (Author/RS)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 412 502

Reading English as a Second Language with Vocabulary Definitions: Cognitive Load Effects on Comprehension and Vocabulary Learning

Alexander Seeshing Yeung

University of Western Sydney, Macarthur

Paper presented at the "Our Schools Our Research" conference

at University of Western Sydney, Macarthur, Australia

on 18 October 1997

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

✓ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN **OTHER THAN PAPER COPY** HAS BEEN GRANTED BY

A. Yeung

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)"

AS012935

BEST COPY AVAILABLE

Abstract

Two experiments were conducted to examine the effects of cognitive load management using vocabulary definitions in reading passages for readers of English as a second language (ESL) with different levels of expertise. Experiment 1 found that vocabulary definitions integrated within a passage (integrated format) improved 5th-grader's comprehension whereas a separate vocabulary list (separated format) improved vocabulary learning. Experiment 2 found that the integrated format improved 8th-grader's vocabulary learning whereas the separated format improved comprehension. The efficiency of instruction depends partly on its ability to manage cognitive load associated with the learning task. An identical presentation format may facilitate learning by reducing cognitive load but may interfere with learning either through split-attention or redundancy effects, depending on the expertise of the learner.

Recent research has indicated that working memory limitations may have an important impact on learning in complex areas (e.g., Just & Carpenter, 1992; Paas & Van Merrienboer, 1994; Sweller & Chandler, 1994). Cognitive load has been identified as an important factor to be considered in instructional design in areas such as science (e.g., Chandler & Sweller, 1991), geometry (e.g., Paas & Van Merrienboer, 1994; Mousavi, Low, & Sweller, 1995), language (Just & Carpenter, 1992), as well as in technical instructions (e.g., Sweller, Chandler, Tierney, & Cooper, 1990; Chandler & Sweller, 1996), and statistics (Paas, 1992). The effectiveness of instruction is at least partly dependent upon its ability to reduce unnecessary cognitive load. The purpose of this study is to examine the cognitive load effects when students are given vocabulary definitions for reading in ESL.

The effects of using vocabulary meanings in reading may be predicted using cognitive load theory (Sweller, 1993, 1994). A separate glossary of word meanings is often found in modern reading material for young readers. This separate glossary may enable the learner to acquire word meanings; but if these meanings must be used for understanding the text, the process becomes more complex. When students encounter an unfamiliar word, they need to leave the text, turn to the vocabulary list, temporarily store the meaning of the word, and then try to incorporate it into the passage. This process of attending to two distinct sources of information may impose a high cognitive load, referred to as the split-attention effect. The effect occurs when learners must split their attention between and mentally integrate multiple sources of information. Researchers have

shown that this may be a problem with some instructional designs (e.g., Chandler & Sweller, 1991, 1992; Sweller & Chandler, 1991, 1994; Sweller, Chandler, Tierney, & Cooper, 1990; Tarmizi & Sweller, 1988; Mousavi, Low, & Sweller, 1995).

In order to reduce the cognitive load due to split attention, some material that requires mental integration of separate sources of information may be modified such that they become physically integrated (e.g., Chandler & Sweller, 1991, 1992; Sweller & Chandler, 1994; Sweller, Chandler, Tierney, & Cooper, 1990; Ward & Sweller, 1990). However, although this technique has proved to be useful in maths and science instruction (e.g., Tarmizi & Sweller, 1988; Sweller & Chandler, 1994), it has not been tested in reading instruction. The technique involves physically integrating, in this case, a text and word definitions so that working memory load due to mental integration is greatly reduced.

Instead of using a separate vocabulary list, word definitions can be provided within a passage. Although this technique is not commonly used in English texts, it used to be found in some classic Chinese literature. The effectiveness of this integrated format of vocabulary meaning presentation has never been seriously assessed. However, it may be expected to avoid the possible split attention of a separated format, such as a separate glossary. In the integrated format, the reader has direct access to word meanings. Because immediacy of processing may reduce storage demands in information processing (Carpenter & Just, 1983; Just & Carpenter, 1980), when vocabulary meanings are readily available, the cognitive load involved in temporary storage should be considerably lowered. Reinking and Rickman (1990) also demonstrated that comprehension may be improved by physically placing word meanings close to target words.

Unless cognitive load reduction is substantial and to such an extent that sufficient mental resources are available for thorough processing of information at all levels of comprehension, while an integrated format should benefit comprehension, vocabulary learning may be hampered (for discussions on levels of processing in comprehension see Goodman, 1976; Gough, 1972; Kintsch, 1988; LaBerge & Samuels, 1974; Stanovich, West, & Feeman, 1981). In contrast, the separated format may result in better vocabulary learning because it is ideally formatted for that purpose, but at the expense of comprehension performance due to split attention. However, facilitative effects of the integrated technique in comprehension should occur only if the vocabulary meanings are essential for comprehension. A student who does not need assistance may only be compelled to process some redundant information. Researchers have indicated that the redundancy effect may be another major obstacle to schema acquisition (e.g., Bobis, Sweller,

& Cooper, 1993, 1994; Chandler & Sweller, 1991; Sweller & Chandler, 1994). Unlike the split-attention effect that occurs when multiple sources of information are essential for comprehension, the redundancy effect occurs when the learner is required to process unnecessary information. It is this processing of unnecessary information that imposes an undue cognitive load.

If the occurrence of the redundancy or split-attention effects is dependent on whether a particular source of information is necessary, then the students' levels of expertise may influence the occurrence of either effect. Although a particular source of information may be essential for less experienced learners and therefore need to be integrated with other information in order to reduce split-attention, for more experienced learners, the same source of information may be redundant. To a young or low-ability reader, when vocabulary definitions are given in an integrated format, more mental resources may be available for comprehension, due to the reduction of split attention. A test of word meanings, however, may find superiority of the separated format because word meanings separated from the text can be learnt without devoting cognitive resources to the text. At least to some children, vocabulary meanings may be more easily learnt from a separate list (Nicholson, 1991). Thus if students are learning word meanings only, the text may be a source of redundancy, but cannot be ignored easily in the integrated format.

Higher-ability readers, in contrast, may find the word meanings redundant when presented in an integrated format, and when required to process them, comprehension may be weakened because of an increase in cognitive load. Because the redundant information is easier to ignore when word meanings are presented in a separate list, comprehension scores should be higher for a separated format whereas reverse results should be obtained on word meaning scores. Students may be able to comprehend words in context but may have difficulty emitting a meaning when required. This task may be easier if word meanings are attended to when integrated with the text. Essentially, for more experienced readers, the integrated format should be better for word meanings because learners are less likely to ignore them. In sum, vocabulary meanings presented in an integrated format may either increase or decrease cognitive load depending on the expertise of the readers and the type of task.

Experiment 1

Experiment 1 examined the effects of vocabulary definitions presented in either an integrated or a separated format with primary school children. The purpose was to examine the effects at both the lexical and semantic levels of comprehension. There were three conditions: (a) vocabulary definitions integrated within the passage, (b) vocabulary definitions listed at the end of

the passage, and (c) a control condition without any vocabulary definitions provided. It was hypothesised that in comparison to the integrated format, a separate list of vocabulary meanings would enhance vocabulary meaning recall but interfere with comprehension because of a split-attention effect, whereas the integrated definitions would facilitate comprehension in comparison to the separated format, but interfere with vocabulary meaning recall because the presence of a passage may distract attention away from precise vocabulary meanings. The focus of this experiment was, therefore, the interaction effect between the integrated and separated conditions at two levels of comprehension processing, i.e., vocabulary learning and passage comprehension.

Method

Participants

The participants were 134 Primary 5 ESL students of a primary school in Hong Kong, ages ranging from 10 to 11 years. They were randomly assigned to three groups.

Materials and Procedure

A passage taken from a standardised comprehension test of the Australian Council for Educational Research (ACER, 1986) for Years 5 and 6 (227 words) was used. Questions were added to the original comprehension test paper so that there were ten multiple-choice questions. Familiar words were used in the questions (all had frequencies greater than 50 per million and two ESL teachers agreed that the questions would not be too difficult for these students). The vocabulary test for each passage was a list of 12 target vocabulary items in a random order for different students.

Participants were randomly assigned to three groups in each of three classes. Vocabulary definitions were inserted above target words in the text for the learning phase in the integrated condition and a list of meanings for the target words were provided at the end of the text for the separated condition. Intact classes were used to present materials and test students.

Integrated condition. During the reading phase, the meaning of each vocabulary item with a frequency of less than 50 per million (Thorndike & Lorge, 1944) was given immediately above the vocabulary item in the passage. For example, immediately above the target word "twisted", its meaning "turned with force" was printed.

Separated condition. Vocabulary meanings were placed in the form of a list immediately after the passage. For example, the target word "twisted" in the passage was printed in a separate glossary with its meaning "turned with force" printed next to.

Control. The passage for the control condition had no word definitions given.

Testing phase. During the testing phase, the original passage was used without any word meanings given. A comprehension test with 10 multiple-choice questions and a vocabulary test with 12 vocabulary items were used to test comprehension and vocabulary meaning recall respectively. The test items of both tests were arranged in four different, random orders to minimise the possibility of students copying from each other. All procedures and time allowed in the testing phase were the same across conditions.

Results and Discussion

The mean correct responses of students (in percentages) and standard deviations in the integrated and separated conditions are shown in Table 1. The data were analysed with a 2 (level: vocabulary and comprehension) x 3 (format: integrated, separated, and control) multivariate analysis of variance (MANOVA) with repeated measures in the level dimension, followed by a simple contrast for the interaction effect between the integrated and the separated conditions. Oneway analyses of variance (ANOVA) were then used to examine the main effects of format at the vocabulary and comprehension levels separately. All statistical analyses were conducted at the .01 level of significance throughout this paper. Results of the MANOVA indicated that the main effect of format was significant, F (2, 131) = 8.82, MSE = 554.73 but the main effect of level was nonsignificant, F (1, 131) = 0.43, MSE = 251.28. The treatment x level interaction was statistically significant, F (2, 131) = 25.55, MSE = 251.28. The focus of this study on the format x level interaction effect was tested using simple contrasts. A significant format x level interaction effect was found between the integrated and separated formats (t = 6.97). Although not of theoretical interest and is presented only for completeness, the format x level interaction effect was also significant between the integrated format and the control (t = 4.86).

Oneway ANOVA at the comprehension level found significant format effects, F (2, 131) = 25.47, MSE = 305.17, and post-hoc Scheffe tests showed that students in the integrated condition performed better than those in the separated or control conditions. Oneway ANOVA at the vocabulary level found significant format effects, F (2, 131) = 7.07, MSE = 500.84, and post-hoc Scheffe tests showed that students in the separated condition performed better than those in the other conditions.

As expected, integrated vocabulary definitions assisted the readers in comprehension of the passage but interfered with the learning of vocabulary meanings which were learnt best as a separate list. Although one might speculate that both conditions providing vocabulary definitions should outperform the control without such provision, the integrated format of vocabulary

definitions did not substantially improve vocabulary scores and the separated format did not substantially improve comprehension. These results can be interpreted by assuming that during text comprehending, the cognitive load involved in the search for meanings and storage of such meanings is reduced if vocabulary meanings are readily accessible when integrated with the text. Under these circumstances, more mental resources can be reserved for processing at the semantic level. Nevertheless, the separated definitions enabled better vocabulary meaning recall because for this purpose, the text becomes redundant. In contrast, during the processing of the passage at the semantic level, the readers had to turn to the vocabulary meaning whenever they encountered a new word, and attention was split. In fact, it was obvious that students in the separated condition had to turn the pages back and forth to obtain the meaning of an unfamiliar word from the separate list and then return to the passage for the processing of meanings in the text. The split-attention effect resulted in lowered performance in passage comprehension, but by ignoring the passage when studying the glossary, performance on the vocabulary test was improved.

Table 1

Means and standard deviations of comprehension and vocabulary test scores (in percentages) of 134 fifth-grade ESL students in three conditions in Experiment 1

		Integrated	Separated	Control
Performance				
	n	44	38	52
Comprehension	M	45.91	26.05	21.35
	SD	(17.16)	(18.39)	(17.04)
Vocabulary	M	28.22	42.98	25.96
	SD	(21.21)	(19.13)	(25.33)

Experiment 2

The purpose of this experiment was to examine the effects of vocabulary definitions using the same integrated and separated techniques of Experiment 1 with secondary school students. For vocabulary definitions to be effective, the passage must impose a high cognitive load to warrant the use of these definitions. If the reader does not need the definitions for comprehension, they may prefer to ignore them. As a consequence, in contrast to Experiment 1, it was hypothesised that for 8th graders might use their own strategies and the syntactic and semantic clues for comprehension instead of making use of the vocabulary meanings provided. Ignoring a

vocabulary list may result in lower vocabulary scores. In the integrated format, the vocabulary meanings, although unnecessary, may be difficult to ignore. Processing of this unnecessary information can result in a redundancy effect which hampers comprehension. Therefore, contrary to the results obtained with 5th-graders in Experiment 1, integrated definitions can be expected to yield lower performance in passage comprehension but higher performance in vocabulary recall when compared with separated definitions. The focus of this experiment is again the format x level interaction effect between the integrated and separated formats, but in an opposite direction.

Method

Participants

The participants were 126 Year 8 ESL students in a school in Hong Kong. They were randomly assigned to three groups.

Materials and Procedure

A passage taken from a standardised comprehension test of the ACER (1986) for Years 7 and 8 was used (300 words). Ten questions were asked in the multiple-choice comprehension test, and the vocabulary test was a list of 12 target vocabulary items in a random order. The procedure was similar to that in Experiment 1.

Results and Discussion

Table 2 shows the means and standard deviations of comprehension and vocabulary performance in percentages. Similar to Experiment 1, the data were analysed with a 2 (level: vocabulary and comprehension) x 3 (format: integrated, separated, and control) multivariate analysis of variance (MANOVA) with repeated measures in the level dimension, followed by a simple contrast for the interaction effect between the integrated and the separated conditions. Oneway analyses of variance (ANOVA) were then used to examine the main effects of format at the vocabulary and comprehension levels separately.

Results of the MANOVA indicated that the main effect of format was significant, F (2, 123) = 15.16, MSE = 261.92 but the main effect of level was nonsignificant, F (1, 123) = 3.25, MSE = 193.79. The treatment x level interaction was statistically significant, F (2, 123) = 23.56, MSE = 193.79. Again, the focus of this study on the format x level interaction effect was tested using simple contrasts. A significant format x level interaction effect was found between the integrated and separated formats (t = -2.97); and also between the integrated format and the control (t = -6.84) although this interaction effect is not of theoretical interest and is not a focus of the present study.

Oneway ANOVA at the comprehension level found that the format effects were nonsignificant, $F(2, 123) = 0.36$, $MSE = 235.08$. However, oneway ANOVA at the vocabulary level found significant format effects, $F(2, 123) = 38.30$, $MSE = 220.63$, and post-hoc Scheffe tests showed that students in both experimental conditions performed better than those in the control group, and the integrated condition outperformed the separated condition.

Table 2

Means and standard deviations of comprehension and vocabulary test scores (in percentages) of 126 eighth-grade ESL students in three conditions in Experiment 2

		Integrated	Separated	Control
Performance				
	n	42	42	42
Comprehension	M	22.86	25.71	24.29
	SD	(14.53)	(15.32)	(16.10)
Vocabulary	M	40.08	30.16	12.10
	SD	(19.93)	(14.83)	(6.69)

As expected, the format x level interaction was significant and in a reverse direction as in Experiment 1 with 5th-graders. Although the main effects at the comprehension level was nonsignificant, since the focus of this study is the format x level interaction that is statistically significant and in the expected direction, there is at least some support for the differential cognitive load effects on different cognitive tasks for learners with different expertise. Perhaps, the list of vocabulary meanings was ignored and treated as if it were a passage in the control. In contrast, the integrated definitions provided vocabulary meanings directly above the target words making them more difficult to ignore. To the 8th-graders using the integrated format, the information contained in the vocabulary definitions may have been largely redundant for the purpose of comprehension. This redundancy resulted in reduced scores (even lower than the control group, although not statistically significant) because the partly redundant vocabulary definitions were unnecessarily processed, but increased scores on the vocabulary test because the definitions could hardly be ignored in this format.

In summary, the occurrence of the redundancy or split-attention effects may be dependent on whether a particular source of information is necessary for intelligibility. Therefore, levels of expertise or experience might influence whether one or the other effect might occur. The reverse

directions of format x level interactions in Experiments 2 and 3 provided evidence that it is not the presentation format of instructional material per se that causes cognitive load differences. The results of these experiments showed that the same presentation format used by learners with differing levels of expertise could result in reverse effects.

General Discussion

The present investigation found that instructional formats used by different learners could yield quite different effects. The two experiments showed that an identical format of instruction yielded reverse effects when used by younger or older ESL learners. Using less expert readers in Experiment 1, by eliminating split-attention, the integrated format reduced the cognitive load related to search for meaning and thus improved comprehension. Nevertheless, while comprehension was improved by an integrated format, vocabulary learning was impeded. Vocabulary learning was learned best when the vocabulary meanings were separated from the text. Under these circumstances, the text acted as a redundant source of information imposing an extraneous cognitive load (Sweller, 1993). In contrast, the more experienced readers in Experiment 2 did not require the vocabulary meanings to comprehend the text. When presented in an integrated format, the meanings were redundant but hard to ignore. They were easier to ignore in a separated format. The redundancy effect increased cognitive load and decreased comprehension when the material was processed in an integrated format. While attending to vocabulary meanings in the integrated format reduced comprehension for more experienced readers, increased knowledge of vocabulary might be expected and was obtained when compared to the separated format that permitted students to ignore vocabulary.

The interaction effects found in the two experiments cannot be explained solely in terms of the nature of the material, or the presentation format, or the learners' abilities. The reverse directions of the interactions provide evidence of effects which have to take into account both the material and the readers' expertise. Because the focus of the present study is on the interaction effects that were hypothesized to be in opposite directions for 5th and 8th grade ESL learners, whether the main effects are significant is not a main concern. Performance may improve only when cognitive load is reduced substantially and to such an extent that mental resources are readily available for information processing. Hence, given a complex cognitive task such as comprehension in a second language, the extent of cognitive load reduction through instructional techniques may not result in dramatic improvement. Furthermore, because comprehension requires complex processing at the lexical, syntactic, and semantic levels almost simultaneously,

reduction of cognitive load by providing vocabulary definitions may not be sufficient for improving performance to a substantial extent.

The pattern of scores and the interaction effects found in the present experiments can be well interpreted in terms of the split-attention and redundancy effects. Even though this does not preclude alternative interpretations of the results, the findings of this investigation have important implications for instructional design. An instructional method or a specific format of presentation may result in facilitation when used with some learners but retardation with different learners. Specifically, for less experienced readers, the integrated format, compared to the separated format, reduced split-attention effects for comprehension but induced redundancy effects for vocabulary learning. In contrast, for more experienced readers, who did not need vocabulary definitions for comprehension, the integrated format induced redundancy effects and hampered performance in comprehension. Thus, when using vocabulary definitions to assist reading activities, it is essential to consider the expertise and previous knowledge of the readers in order to use either an integrated or separated format of presentation for a specific purpose. A detailed analysis of both the material used and the students who will be using it is required before an ideal instructional format is devised. This analysis will benefit students of differential expertise and experiences in reading activities as well as in other learning activities. There is at least some evidence that cognitive load theory can assist in this analysis.

References

Australian Council for Educational Research (1986). Progressive achievement tests in reading (2nd ed.). Victoria: Brown prior Anderson.

Bobis, J., Sweller, J., & Cooper, M. (1993). Cognitive effects in a primary-school geometry task. Learning & Instruction, 3, 1-21.

Bobis, J., Sweller, J., & Cooper, M. (1994). Demands imposed on primary school students by geometric models. Contemporary Educational Psychology, 19, 108-117.

Carpenter, P. A., & Just, M. A. (1983). What your eyes do while your mind is reading. In K. Rayer (Ed.), Eye movements in reading: Perceptual and language processes (pp. 275-307). San Diego, CA: Academic Press.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. Cognition and Instruction, 8, 293-332.

Chandler, P., & Sweller, J. (1992). The split-attention effect as a factor in the design of instruction. British Journal of Educational Psychology, 62, 233-246.

Chandler, P., & Sweller, J. (1996). Cognitive load while learning to use a computer program. Applied Cognitive Psychology, 10, 151-170.

Goodman, K. S. (1976). Reading: A psycholinguistic guessing game. In H. Singer & R. Ruddell (Eds.), Theoretical models and processes of reading. Newark, DE: International Reading Association.

Gough, P. B. (1972). One second of reading. In J. F. Kavanagh & I. G. Mattingly (Eds.), Language by ear and eye. Cambridge: MIT Press.

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixation to comprehension. Psychological Review, 87, 329-354.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. Psychological Review, 99, 122-149.

Kintsch, W. (1988). The use of knowledge in discourse processing: A construction-integration model. Psychological Review, 95, 163-182.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. Cognitive Psychology, 6, 293-323.

Mousavi, S., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. Journal of Educational Psychology, 87, 319-334.

Nicholson, T. (1991). Do children read words better in context or in list? A classic study revisited. Journal of Educational Psychology, 83, 444-450.

Paas, F. G. W. C. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. Journal of Educational Psychology, 84, 429-434.

Paas, F. G. W. C., & Van Merrienboer, J. J. G. (1994). Variability of worked examples and transfer of geometrical problem-solving skills: A cognitive-load approach. Journal of Educational Psychology, 86, 122-133.

Reinking, D., & Rickman, S. S. (1990). The effects of computer-mediated texts on the vocabulary learning and comprehension of intermediate-grade readers. Journal of Reading Behavior, 22, 395-411.

Stanovich, K. E., West, R. F., & Feeman, D. J. (1981). A longitudinal study of sentence context effect in second-grade children: Tests of an interactive-compensatory model. Journal of Experimental Child Psychology, 32, 185-199.

Sweller, J. (1993). Some cognitive processes and their consequences for the organisation and presentation of information. Australian Journal of Psychology, 45, 1-8.

Sweller, J. (1994). Cognitive load theory, learning difficulty and instructional design. Learning and Instruction, 4, 295-312.

Sweller, J., & Chandler, P. (1991). Evidence of cognitive load theory. Cognition & Instruction, 8, 351-362.

Sweller, J., & Chandler, P. (1994). Why some material is difficult to learn. Cognition and Instruction, 12, 185-233.

Sweller, J., Chandler, P., Tierney, P., & Cooper, M. (1990). Cognitive load and selective attention as factors in the structuring of technical material. Journal of Experimental Psychology: General, 119, 176-192.

Tarmizi, R., & Sweller, J. (1988). Guidance during mathematical problem solving. Journal of Educational Psychology, 80, 424-436.

Thorndike, E. L., & Lorge, I. (1944). The teacher's word book of 30,000 words. New York: Columbia University.

van Dijk, T. A., & Kintsch, W. (1983). Strategies of discourse comprehension. San Diego, CA: Academic Press.

Ward, M., & Sweller, J. (1990). Structuring effective worked examples. Cognition and Instruction, 7, 1-39.